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Titel: Design of the wastewater treatment system for the Mae Hia Agricultural Research Station and Training Center

This essay is an extract of a report about the planning of the "Mae Hia waste Water Treatment System" elaborated in November 1989 in Braunschweig-Königlutter, Germany.

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Session 1:
Treatment of wastewater with a high content of suspended solids

Design of the waste water treatment system for the Mae Hia Agricultural Research Station and Training Center

by Rolf Kloss[+)]

1. Background of the planning activities

The aim of the Thai-German Biogas Programme is the extension of biogas technology within four northern provinces of Thailand. The project is split up into two work phases:
Mainly, smaller farmers are reached by an agricultural counselling service (DoAE - Regional office).
New solutions for the disposal of waste and the utilization of gas in medium-sized pig and dairy-cattle farms are to be found via the use of research and development (Chiang Mai University). Aspects of environmental protection are equal to or higher than the aspects of the gaining of energy. Especially the keeping of pigs is increasingly becoming part of public discussions due to the high emissions. These discussions are being fired even further at present by the fact that the decision has been made in the neighbouring state of Singapore to stop the keeping of pigs completely. Corresponding legislative measures for the solution of the emission problems can now also be seen in Thailand.

2. The task

As a contribution to the technical solution of the problems, a progressive waste-disposal concept is to be presented through the example of the "Mae Hia Agricultural Research Station and Training Center" of the University of Chiang Mai, which can be transferred at short notice at least in parts to the problems of the region. At the research station both cattle and pigs are kept for teaching and demonstration purposes.

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3. Mae Hia Agricultural Research Station and Training Center

3.1. Position, climatic data

The Mae Hia Agricultural Research and Training Center is in the South West of Chiang Mai at a height of about 310 meters above sea level, near the mountain Doi Suthep, 1296 m high.
The mean daily temperatures are, in the course of the year, between 20 and 28 °C, the lowest temperatures in the ground 19°C. The precipitation mainly falls in the monsoon period, i.e. from May to September. August is the month with the greatest precipitation with up to 16.6 cm per day.

3.2 Sties and waste water disposal

The Research Area is spilt into two building complexes by two pools (cf. figure 1).

3.2.1 Keeping of cattle

At present, about 40 cattle are being kept in a number of sheds. These are mainly loose housings and tie-up sheds. The calves are several deep litter houses, which are given fresh straw and are cleared of excrement every day.

Mainly Friesian cattle are kept, which are normally fed with gras. The stock corresponds to about 32 livestock units (LU) as regards the weight, from which an amount of liquid manure of 1.6 m3/d results.

The cleaning of the sheds is carried out by means of spraying the concrete shed floor. About 2.6 m3/d of washing water are used for this every day, which increases the daily amount of waste water to about 4.2 m3/d. Disposal of water from the sheds is carried out by means of longitudinal and transverse channels to a communal collector, and from there via piping to the deepest lagoon.

Further extension of the keeping of cattle is not being considered for the near future.

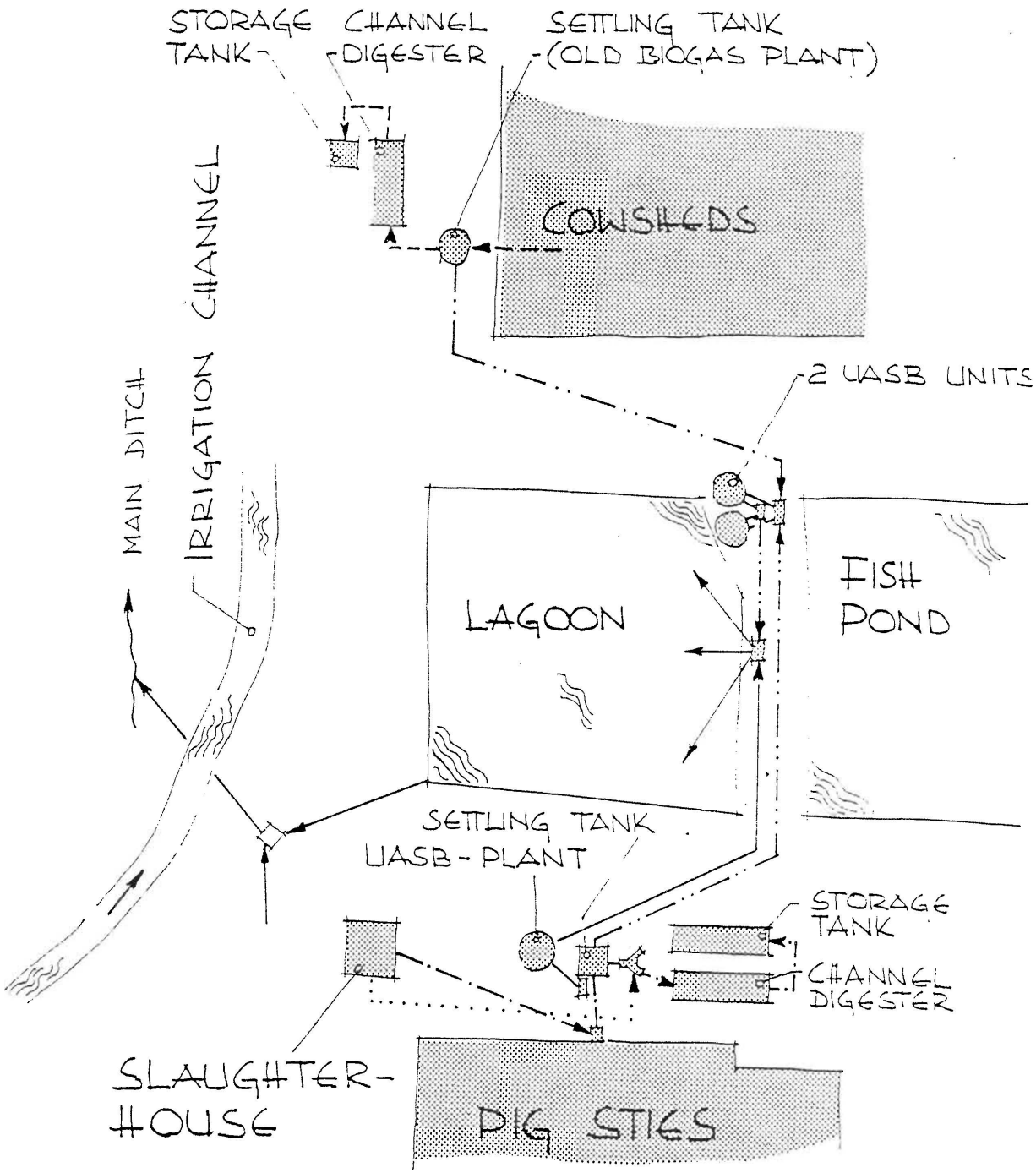

Fig. 1: Treatment concept schematically

- - - - Line 1: sedimentable cattle manure (sludge treatment)
-·-·- Line 2: sedimentable pig manure and slaughterhouse waste water (sludge treatment)
——— Line 3: pretreated pig manure and slaughterhouse waste water
····· Line 4: solid wastes from the slaughterhouse (solids treatment)
—··— Line 5: pretreated cattle manure, pig manure and slaughterhouse wastewater (liquid treatment after increasing the pig livestock)

3.2.2 Keeping of pigs

Up to 200 animals are kept in sties without straw, corresponding to about 31 LU. Like the cattle sheds, the pigsties have no slotted floors. They are cleaned and the water is disposed of in the same way. This results in 1.15 m3/d of animal excrements and 5 m3 of washing water, which reach the lagoon in the same way as in the keeping of cattle. The waste water from both sties is to clean itself in the lagoon before passing on to a collector with the water from other pools. This collector goes below the irrigation channel leading past the research area. From there, the collector flows on to the nearest main ditch.

Increasing the amount of animals by about 500 units to a total of 700 pigs is being considered for the near future.

3.3 Slaughterhouse

The Research Station will also be extended by a slaughterhouse, which is to have a treatment capacity of up to one ton of live weight killed (LWK) per week.

3.4 Existing biogas plants

Alongside the stalls, there are also two biogas plants on the research area, which were put up on the center years ago to introduce biogas technology. One biogas plant was built to deal with the excrement from the keeping of cattle and one for the pig excrement.

Due to serious errors in the planning, the biogas plant treating the animal excrement from the keeping of pigs went out of operation again after a short time.
The biogas plant - a floating drum system - put up for the keeping of dairy cattle, which is 8 m3 in size, was operated for 5 years more or less free of large interruptions.

At the point of time of removal from operation in the month of May. this year, the plant was fully "sludged up" by flotating and

sedimentable solid matter, which had led to a quite considerable reduction in the gas production. The actual active volume of the sludge-digestion tank was only about 2 cubic meters. The plant was therefore also taken out of operation and cleared out.

Both plants had mainly been produced to gain energy. Deliberate application of the sludge for purposes of manure was not carried out.

4. Analysis of the existing waste-disposal concept

The dirt freight which reaches the lagoons for waste water cleaning from the sheds is about 309 kg COD and corresponds to 2,400 population equivalents (P.E.).
If the amount of animals is increased by 500 further animals and the slaughterhouse is put up, then the dirt freight will increase by a further 293 + 14 to 616 kg COD daily. This practically corresponds to doubling.
If this pollution is to be cleaned in a lagoon in such a way that acceptable values are reached in the area of under 20 mg/l BOD_5, then a surface of approx. 86,000m2 is necessary to insert the oxygen, corresponding to a square with a side of nearly 300 m. Using alternatively water hyacinths on the lagoon surface half of this surface under the climatic conditions in Chiang Mai should still be sufficient.

The actual surface of the lagoon is a long way below this value, approx. 3,000 m2. Accordingly, the cleaning performance of the existing system is only very low.
There is no alteration in this situation even if we take into consideration that a part flow of the waste water could be treated by the biogas plant, which is next to the cattle sheds and is not in operation at present.
The reaction volume of the existing plant is simply much too low for this.

To sum up, it can be seen that the waste water situation at the Research and Training Center is very tense at the present. It will

become even worse in future if the present waste water cleaning concept remains unaltered.
An improvement of this local situation is to be aimed at for reasons of environmental protection.

5. Waste and wastewater disposal concept

Due to the restricted space, relief of the main ditch cannot be carried out by means of waste water lagoons, but can only be achieved by means of an intensive cleaning method.
Amongst the existing cleaning methods, anaerobic cleaning is interesting due to the concentration and the climatic temperature conditions.
Although almost the same steps of treatment are necessary for the treatment of the waste water on the premises of the keeping of cattle and pigs, joint treatment is not possible due to the distances and the difference in altitude between the two venues.
Thus, there are several lines for the treatment of the various waste waters and waste (cf. Figure 1).
In line 1, only the sedimentable part of the liquid cattle manure is treated.
Line 2 treats the sedimentable part of the liquid pig manure and the slaughterhouse waste water.
In line 3, the anaerobic treatment of the liquid pig manure and slaughterhouse waste water, pre-treated by sedimentation, is carried out.
Line 4 treats the non-flowable solid matter which comes about at the Research Station.
Line 5 cleans the waste water from the keeping of cattle, which has been pre-treated through sedimentation together with the waste water from the keeping of pigs, which will additionally come about if the stock of pigs is increased.

The concept worked out plans in detail that the liquid cattle manure is put together in a collecting channel and fed to a settling tank with a thickener via a drain (line 1).
Then the thickened manure reaches a channel-shaped biogas plant.
After digestion, the liquid manure is collected in a storage tank

Table 1 : Current situation of mass flows by the introduction of an anaerobic pretreatment process

Substrates	Dim.	cattle manure	pig manure	slaughterhouse waste water	slaughterhouse solid waste	Total
I Before settling tank:						
Volumes	m3/d	4.2	6.2	1.0	0.06	11.4
COD-Freights	kg/d	192	117	2	12	323
II To the two channel digesters:						
Volumes	m3/d	1.4	0.7	0	0.01	2.1
COD-Freights	kg/d	115	59	0	12	186
Converted into biogas	kg/d	44	28	0	12	84
III After settling tank to the UASB plant for further treatment of the pig-manure and slaughterhouse waste water						
Volumes	m3/d	-	5.5	1.0	0	9.3
COD-Freights	kg/d	-	58	2.0	0	137
Converted into biogas	kg/d	-	22	2.0	0	24
IV To the lagoon						
Volumes	m3/d	2.8	5.5	1.0	0	9.3
COD-Freights	kg/d	77	36	0.0	0	113

Note:
After the treatment steps, the total removal of COD is without treatment of the liquid-flow from the settling tank of the keeping of the cattle: nCOD = 1 - (113/323) = 65 %. By complete anaerobic treatment of all flows, a maximum efficiency of 1 - (82/323) = 75 % can be reached.

following the biogas plant and is disposed of following corresponding intermediate storage as manure ready for use on plants.

Just like the liquid cattle manure, the liquid pig manure, to which washing water is added to a much higher degree for operational reasons, is firstly fed into a settling tank with a thickener (line 2). The slaughterhouse waste water is also added to the latter in order to separate matter which sinks, after it has already passed through a comb and a sand-trap. The separated sludge which comes about in the thickener is also further treated as explained in line 1.

The residue from line 2 which has been separated in the settling tank and freed from sedimentable solid matter is subjected to an anaerobic further treatment (line 3). In this phase, the waste water is freed and cleaned from the dissólved organic compounds, in so far as they can be cleaned by the anaerobic bacteria.
After this, they are further treated aerobically in the lagoon - as has been the case up to now - from where they then finally pass on to the main ditch.

The idea of transferring the non-flowable organic solid matter coming about in the center to compost, which had originally been considered (line 4), was dropped. The solid matter does not represent an excessively great problem, which means that there is no acute need for action in this regard.
With the construction and start of operation of the slaughterhouse, there will however be real problem matters, e.g. in form of stomach, intestinal and rumen contents. The planned solution for the disposal of this matter is to transport it in a wheelbarrow to the input drain of the channel biogas plant which treats the thickened liquid pig manure, and to feed it into the channel digester there. In accordance with experience made by different authors, excellent decomposition of the matter is to be expected.

As the calculations made in this regard show (cf. Table 1), the waste water occurring at present including the matter caused by the slaughterhouse can be cleaned with a total degree of efficiency of 65% according to this concept.

This degree of efficiency could also be increased to 75% if the residue from the keeping of cattle freed from sedimentable matter were fed on to further treatment. Such a treatment step is however not planned for this phase due to the relatively low freights and for cost reasons.
Should the plans for the extension of the keeping of pigs however become reality, then this treatment step would also become sensible. With the extension of the keeping of pigs, the dirt freights coming about up to now would double, which means that a further disposal line must be set up. In this case, it would be the obvious thing to treat the additional amounts of waste water coming about with a further anaerobic plant, whereby it will be sensible this time to combine the waste water flows from the keeping of cattle and the keeping of pigs (cf. figure 1, line 5).

If the five lines were realized, the 616 kg COD, which would come about from today's point of view, could be cleaned with a total degree of efficiency of up to 73% (table 2). A further increase of this degree of cleaning is not possible by means of anaerobic methods, but can only be achieved by subsequent use of aerobic methods of treatment. The degree of cleaning can thus be increased by subsequent connection to the lagoon, and it is estimated that discharge values around 50 mg BOD_5/l can be reached in this way.
Should these values be fallen short of, then further measures are necessary. A sensible measure could, for example, be the additional ventilation of the lagoon by means of irrigation over land.

6. Realization of the concept

With regard to the existing environmental situation, the aim of the project must be to achieve a lasting improvement and relief of the conditions as soon as possible.
Agreement was reached, that the concept be realized in four steps and in the following order:
1st. step:
Realization of lines 2, 3 and 4.
2nd. step:
Realization of line 1.
3rd. step:

Table 2 : Future situation of mass flows by the introduction of anaerobic pretreatment and after increasing the population of pigs kept from 200 to 700 units

Substrates	Dim.	cattle manure	pig manure	slaughterhouse waste water	slaughterhouse solid waste	Total
I Before settling tank:						
Volumes	m3/d	4.2	21.7	1.0	0.06	27.0
COD-Freights	kg/d	192	410	2	12	616
II To the two up to three channel digesters:						
Volumes	m3/d	1.4	2.5	0	0.01	3.9
COD-Freights	kg/d	115	205	0	12	332
COD converted into biogas	kg/d	44	84	0	12	140
III After settling tank to the UASB plant for further treatment of all liquid flows						
Volumes	m3/d	2.8	19.2	1.0	0	23.0
COD-Freights	kg/d	77	205	2.0	0	284
COD converted into biogas	kg/d	31	82	2.0	0	115
IV To the lagoon						
Volumes	m3/d	2.8	19.2	1.0	0	23.0
COD-Freights	kg/d	46	123	0.0	0	169

Note:
By the complete anaerobic treatment of all flows, a maximum efficiency of 1 - (169/616) = 73 % can be reached.

Realization of line 5.

4th. step:

Improvement of the cleaning performance of the lagoon.

7. Planning and dimensioning of the constructions

Step 1:

Treatment of the waste water and waste from the keeping of pigs and the slaughterhouse (lines 2, 3 and 4)

The planning of step 1 led to the following dimentions for the different installations, which are necessary:

1. Settling tank with thickener:
   Surface: 2.6 x 2.6 m, Depth: 4.5 m.
2. Channel biogas plant for the treatment of sludge:
   Volume: 2 x 100 m^3 (One of these two plants will be used as a sludge storage tank until the pigs will be increased from 200 to 700 units.).
3. Unaerobic sludge blanket biogas plant (UASB) for the purification of the wastewater:
   Volume: 50 m^3. Depth: aprox. 4.5 m.

9. Gas yield and utilization

Using the present livestock and the construction of the slaughterhouse as a basis, we can expect the following methane yields (cf. table 1 and 2):

- from the treatment of the sludge of the lines 2 and 4 in the 100 m3 channel digester: 9.8 + 3.0 = 12.8 m3/d
- from the 50 m3 UASB pilot plant: 8.4 + 0.2 = 8.6 m3/d

  total: 21.4 m3/d

  = 150 kWh/d = 6 kW.

Should the pig livestock at the center be increased as planned and the anaerobic treatment lines be extended as shown, then this methane yield will be more.

The present plan is that the biogas coming about in the plant be fed via a collector conduit to the refrigerator of the slaughterhouse, where it is to be used via a gas-engine cooling machine. As storage of gas is always extraordinarily expensive, we suggest that it be waived as far as possible in the conception of the utilization of the gas instead other forms of energy storage be investigated. Supplies of ice and iced water are one possibility, with which the peaks of the energy required by the slaughterhouse, caused by the process of cooling the freshly slaughtered half-animals, can be covered.
Should however a certain gas buffer be necessary, then it should be considered that small amounts of biogas can be stored in the UASB plant.

Addendum: Chiang Mai, 25th of September 1990

Respectively to the previous planning the step 1 could be translated into reality at December 1990, so that the whole plant was taken into operation at that moment. Fig. 2 shows the main components of the plant.
Up to now the plant has been working without any functional problem. At present the plant is being evaluated.
The actual amount of livestock units with about 45 LU (350 fattening pigs) is 14 LU higher than initially was taken into account. This is also true for the consumption of washing water for the stables. Here are used actually 23 m^3 daily instead of 6 m^3 previously measured.
The first data obtained from the plant show now, that even under these higher hydraulic and organic loadings the plant works more efficient than the results obtained from former calculations predicted. This leads furthermore to the conclusion, that it might be possible to treat the whole contamination generated by the Mae Hia farm without any expansion of the existing plant even then, when additionally the meanwhile and much earlier than it was assumed constructed new stables with about further 700 pigs will be taken into operation.

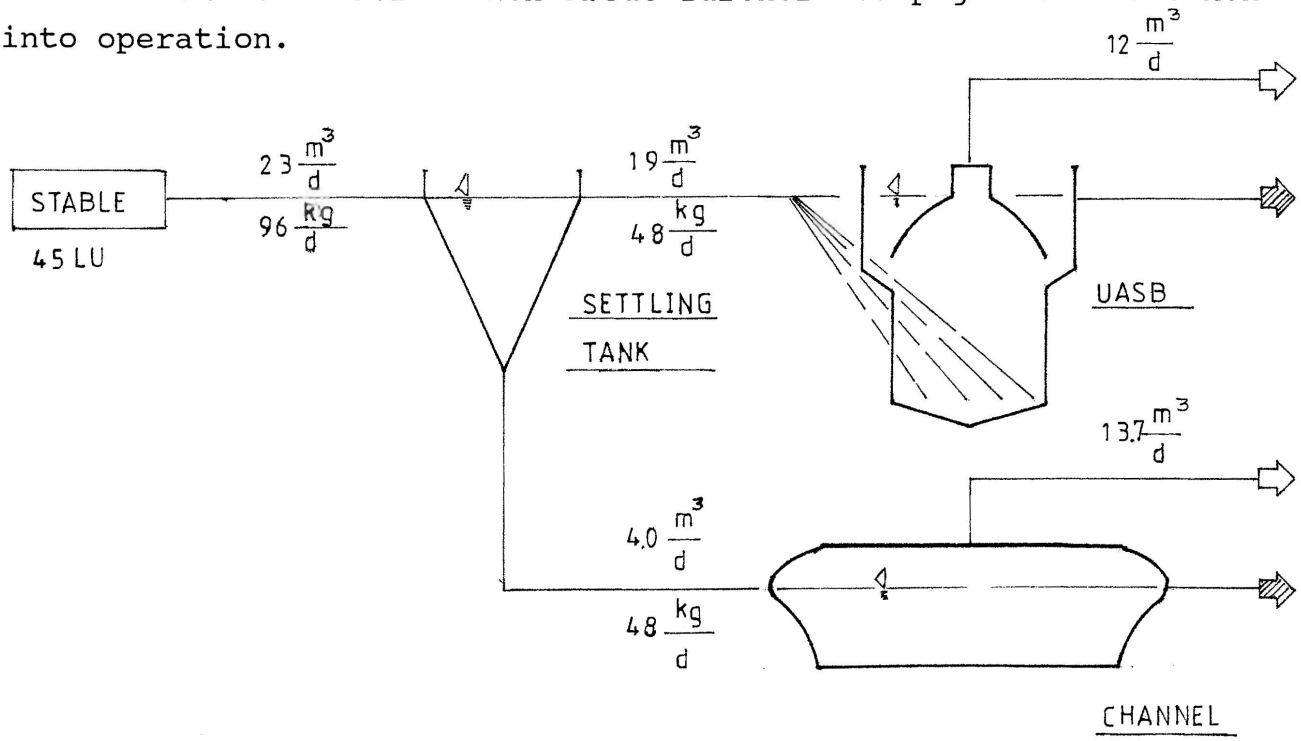

Fig. 2: Main elements of the "Mae Hia Biogas-System".
Volumetric and mass flow rates (as total solids).
⇨ Methane ⇨ Wastewater